DWARFMISTLETOE CONTROL OPPORTUNITIES in Ponderosa Pine Reproduction

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U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

NOVEMBER 1963

FOREWORD

This paper is intended to serve merely as an interim guide to dwarfmistletoe control. Until research provides an adequate basis, the factors involved can be described only in broad terms, and the efficiency of a control project must depend largely on the personal judgment and experience of the forester in charge. Nevertheless, certain general principles have been derived from observations, pilot-scale projects, and the scanty research data obtained thus far. These principles can be used to determine where and how dwarfmistletoe control should be undertaken now.

Several foresters concerned with the dwarfmistletoe problem, especially Bernard G. Duberow, Donald P. Graham, Benton Howard, and Charles H. Overbay, contributed ideas to the discussions and pilot control projects which are part of the background of this paper.

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FOREST SERVICE,
Portland, Oregon
November 1963

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INTRODUCTION

Seeds of ponderosa pine dwarfmistletoe *(Arceuthobium campylopodum* f. *campylopodum)*, unlike the tiny spores produced by most pathogens, rarely travel far. Since most new infections occur on the side of the crown toward the source of inoculum,[1] spread by subsequent generations of the parasite enlarges the infested area only slowly, though it often results in rapid and severe intensification of the disease within the infested area. Reproduction within a chain or so of infected old-growth trees may become heavily infected in the course of only a few years, but under ordinary conditions in even-aged ponderosa pine *(Pinus ponderosa)* types, spread from infested areas into contiguous uninfested areas appears to be less than 100 feet during a rotation.

Control of dwarfmistletoe by local sanitation – that is, by eradicating infected trees or parts of trees from relatively small areas – can accordingly be accepted as biologically sound, even though our knowledge of details of the parasite's behavior is still far from adequate. Today's control methods, however, are so costly under some conditions (for example, where most of the reproduction is large and heavily infected) that control on much of our infested acreage is impractical at present. Economic soundness of control cannot be determined, for the various combinations of conditions existing within pine forests, until rates of intensification of the disease and its effects on yields have been measured more accurately.

But while we wait for a complete analysis of economic relationships or better methods of control, we are losing opportunities that will not occur again for a century or more.

Neither young stands nor dwarfmistletoe infestations are static, especially after overstories have been opened. Saplings become poles, infections multiply, infested areas expand, and control costs increase correspondingly from year to year.

[1]Roth, L. F. Pine dwarfmistletoe on the Pringle Falls Experimental Forest. U.S. Forest Ser. Pac. NW. Forest & Range Expt. Sta. Res. Note 91, 3pp. 1953.

Under favorable conditions, control even by present methods is obtainable at low cost by combining sanitation with other operations.[2] On almost innumerable small to large areas, probably aggregating well over a hundred thousand acres in the Pacific Northwest alone, relatively small expenditures for control during the next few years will increase yields from the next rotation and reduce the size of the control job that must eventually be done.

GENERAL CONSIDERATIONS

Except in lightly infested and sparsely stocked young stands, control is now economically practical only where thinning is practical. In overstocked stands, sanitation must always be accompanied by thinning, since (1) growth in crowded stands will be insufficient to yield an adequate return on the sanitation investment and (2) the two operations will cost less in combination than separately. Conversely, thinnings of infested stands must always be accompanied by sanitation, since the disease, if uncontrolled, will greatly reduce the returns from the thinning investment.

Growth impact of dwarfmistletoe varies widely with variation in severity of infection, but from the data now available it is reasonable to assume, as a general rule of thumb, that control is economically sound where (1) thinning would be economically sound if the stand were not infested and (2) the net cost of control – that is, the cost of the combined sanitation-thinning operation minus what the thinning alone would have cost – is less than one-fifth of the capitalized total potential yields from the protected acreage. (In estimating control costs, allowance must be made for a second coverage of the area a few years after the first one to remove latent and missed infections. In sapling stands this cost ordinarily should be less than $4 per acre.)

[2]Unpublished cost studies by John Fedkiw and D. F. Flora, Pac. NW. Forest & Range Expt. Sta.

It must be remembered that economic soundness of control in any given instance is determined entirely by the answer to just one question: Will the operation yield a profit? If control will result in understocking but will increase productivity more than enough to pay the costs of the operation, then control is economically sound regardless of its effect on stocking. Drastic treatments, such as clear cutting and broadcast burning, may sometimes be advisable on extremely heavily infested areas. Conversion to some other locally common and healthy tree species is an occasional alternative. Where the principal objective is timber production, the forester's proper goal is not to maintain a given forest type or degree of stocking but to obtain the maximum value return from the managed acreage.

It is obvious that higher costs can be tolerated on good sites than on mediocre ones and that control will seldom be practical on poor sites. Within wide limits, suitability of areas for control is largely at this time a question for informed personal judgment. External factors, such as interest rates used in discounting expected returns, importance of objectives other than timber production, and availability of permanently employed labor during slack periods in other work, must all be considered but are beyond the scope of this paper.

Within the forest, the factors involved occur in so many combinations and have been so little studied that only general guidelines can be given. Practicability of control on fairly good sites and details of the procedures to be followed depend principally upon (1) habits of the parasite, (2) size and shape of infested areas, (3) intensity and distribution of infection on reproduction, and (4) structure of the understory.

HABITS OF THE PARASITE

Infected overstory trees are the worst sources of understory infection. Since uninfected mature trees cannot be recognized with certainty, control units must be clear cut. When ripe seeds are present (usually late

August to early October), infected trees should not be felled into healthy reproduction.

In closed but nonstagnated young stands that have not been exposed to overstory infection for a dozen years or more, the most rapidly growing trees are often nearly free from infection above midcrown. Where pruning for quality increment is practical, such trees can be cleaned at little or no cost to the sanitation part of the operation.

Dwarfmistletoe plants ordinarily do not become visible until 3 to 5 years after the seeds have germinated. At the earliest, they do not fruit until the end of the second growing season after their appearance. To permit most of the latent infections in the reproduction to appear, without allowing them much time to spread new infection to neighboring trees, the first sanitation should be 4 or 5 years after removal of the overstory and the second after another 4 or 5 years. Sanitation immediately after clear cutting is likely to increase total costs, since two reworkings may then be necessary. The final result, however, will probably be a cleaner stand. Whenever possible, in all except the final sanitation, enough surplus reproduction should be left so that the stand will not be opened excessively by removal of infected trees during later sanitations.

Dwarfmistletoe infection appears able to intensify rapidly enough that fairly light infestations in young stands can become damaging by the end of the rotation. If this is a common occurrence, control may prove more profitable in lightly infested stands because of the higher total costs in heavy infestations. In any event, the parasite responds so quickly to release and fruits so much more prolifically on vigorous hosts that sanitation must be thorough in order to protect thinning investments. Complete elimination of the parasite is too expensive to be practical under most conditions, but infection must be reduced to a low level for satisfactory control.

Trees of other species, even when heavily infected, seldom spread damaging infection to ponderosa pine. They can sometimes be used as physical barriers to impede spread from one ponderosa to another.

SIZE AND SHAPE OF INFESTED AREAS

Infestations vary from less than an acre to more than 1,000 acres in extent. They are vaguely bounded, are often of irregular shape (fig. 1), and tend to occur in groups rather than at random. Intervening uninfested zones vary from a few yards up to many miles in width.

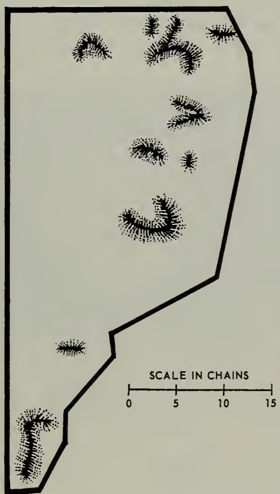

Figure 1. — Dwarfmistletoe infestations (hachured) on 103 acres in a young sawtimber stand.

Data in table 1 (from surveys made for other purposes) illustrate the diversity in size of infested areas. Some of the intercepts recorded in this table were through narrow salients from large infestations and others were through more or less elongated areas of infestation, but the intercept lengths are roughly indicative of dimensions of infested areas. In the first two stands, it was evident from brief observations that dwarfmistletoe commonly

Table 1.– Frequency distribution of line intercept lengths[1] through infested and uninfested areas in three stands on the Deschutes National Forest

Intercept length (chains)	Stand "A"		Round Mountain		Squaw Creek	
	In-fested	Unin-fested	In-fested	Unin-fested	In-fested	Unin-fested
	Percent of intercepts					
2	56	17	36	39	18	38
4	24	13	25	21	14	14
6	12	8	17	7	7	19
8	3	11	4	11	10	19
10	3	12	6	7	7	–
12	1	5	2	7	–	–
14	–	4	7	2	3	5
20	1	16	2	5	3	5
30	–	9	1	1	3	–
40	–	1	–	–	3	–
50	–	2	–	–	7	–
60	–	1	–	–	–	–
80+	–	1	–	–	25	–
Total	100	100	100	100	100	100

[1]Exclusive of incomplete intercepts at ends of survey lines.

occurred in small patches. At Squaw Creek, infestation was usually continuous over long distances, and many of the uninfested areas were not ponderosa type or were merely small enclaves entirely surrounded by infestation.

Where entire infested areas can be sanitized and especially if they are small and elongated or irregular, higher control costs per acre can be tolerated because the acreage protected is greater than that actually treated (fig. 2). On the assumption that infection will otherwise spread in damaging intensities for a distance of 1 chain

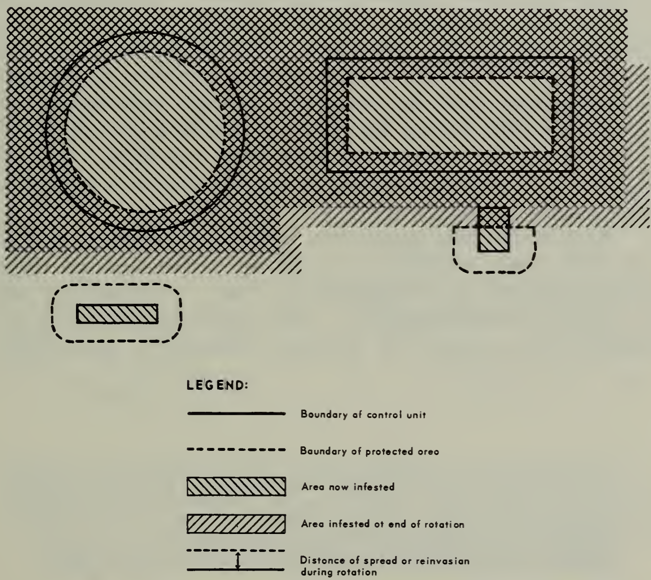

Figure 2. Theoretical relations between treated and protected areas.

into the surrounding stand during the rotation, then complete sanitation of isolated infestation 2 chains wide and 4 chains long will protect an area about 4 by 6 chains in extent—almost three times the acreage on which the costs were incurred. Similarly, sanitation of an infestation salient 1 chain wide and extending 2 chains from the main area of infestation will protect more than one-half acre (about 2 by 3 chains) even though the square chain of treated area nearest the untreated main area of infestation will be reinvaded to a damaging extent during the rotation.

The reverse is true where only parts of large infestations are sanitized. The larger the control unit in such instances and the shorter its perimeter in proportion to its area (i.e., the more nearly circular it is), the more efficient will be the operation. For example, a circular control unit 10 chains in radius and entirely surrounded by infestation will be reduced, through reinvasion, by almost one-fifth during the rotation; while a unit 5 chains in radius will be reduced by more than one-third. A 6- by 10-chain unit will be reduced to 4 by 8 chains – a loss of nearly half in net acreage.[3]

Reinvasion can sometimes be prevented along part of a control unit perimeter by taking advantage of ridge crests, patches of non-ponderosa types, or other barriers to spread of the parasite. The worst boundary is one immediately adjacent to infested old-growth ponderosa.

[3]For circular and rectangular units, these relationships are given by the following formulas in which P = proportion of protected to treated acreage; R = radius, L = length, and W = width of control unit; and D = distance over which damaging spread will occur during one rotation (assumed, in the above examples, to be 1 chain).

Circular units that include entire infestations: $P = \frac{(R+D)^2}{R^2}$

Rectangular units that include entire infestation:

$$P = \frac{LW+2DW+2DL+\pi D^2}{LW}$$

Circular units surrounded by infestation: $P = \frac{(R-D)^2}{R^2}$

Rectangular units surrounded by infestation: $P = \frac{(L-2D)(W-2D)}{LW}$

INTENSITY AND DISTRIBUTION OF INFECTION ON REPRODUCTION

Infection is more abundant on large reproduction than on small (fig. 3). Larger trees interpose more crown across the flight paths of dwarfmistletoe seeds, are less often screened from sources of infection by intervening trees, and have usually been exposed for more years.

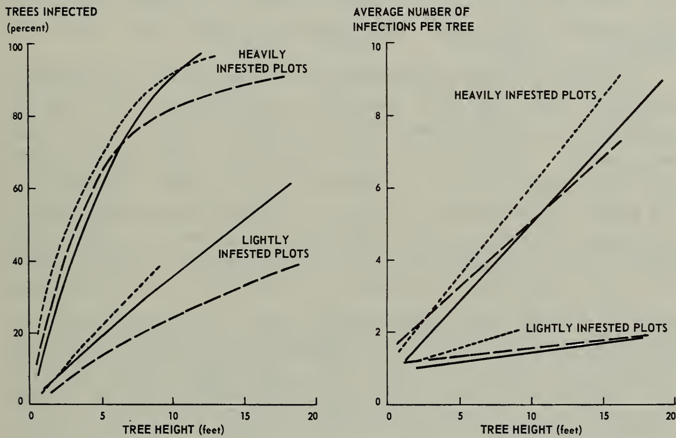

Figure 3.—Percentages of trees infected and average numbers of infections per infected tree, for trees of different heights on infested plots in three sapling stands (solid lines represent Round Mountain stand; broken lines, stand "B"; and dotted lines, Squaw Creek).

With some exceptions (for example, where a lightly infected tree is otherwise far superior to its immediate neighbors, or where its removal will leave a large gap in the stand), infected trees should not be selected for crop trees even if all visible infections can be removed. Pruning is expensive, and the more heavily infected the tree, the more likely it is to bear latent or overlooked infections (table 2). Sanitation in heavily infested stands consequently must eliminate practically all the poles and, if the stand consists mostly of poles, will result in serious reduction of stocking as well as sacrifice of accumulated growth. In lightly infested stands, many of the small poles and even some of the large ones can often be saved.

Stands of large poles that are not more than moderately infected and are still growing reasonably well can be expected to yield some usable material within relatively few years. Control in such stands is often impractical, not only because of its direct cost but also because of its high indirect cost – that is, the sacrifice of potential volume. However, where infection is severe in small-pole stands, the commercial crop will probably be negligible.[4] In such instances, sacrifice of stocking or accumulated growth will be more apparent than real, and control can be considered practical if its direct costs are less than the capitalized value of the crop expected after control.

Sapling stands, unless exceptionally sparse or extremely heavily infested, almost always include enough uninfected trees well enough distributed to provide at least fair stocking after sanitation (table 3). Although uninfected trees average smaller than their infected neighbors and are sometimes badly suppressed, most of them will grow well when released.[5]

[4]Leaphart, Charles D. Dwarfmistletoes: a silvicultural challenge. Jour. Forestry 61: 40-46, illus. 1963.

[5]Dahms, Walter G. Long-suppressed ponderosa pine seedlings respond to release. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 190, 3 pp. 1960.

Table 2.— Percentages of crop trees with latent or missed infections, on experimental sanitation-thinning areas in two heavily infested stands of large saplings

Infected branches cut in sanitation	Crop trees (basis)		Trees found infected	
	Green Mountain	Pole Spring	Green Mountain after 3 years	Pole Spring after 1 year
	Number	Number	Percent	Percent
0	185	179	29.7	6.1
1	44	25	47.7	28.0
2	21	11	71.4	54.5
3 or more	15	14	86.7	64.3

Where little or no surplus reproduction is present, practically complete protection of the understory during logging can be obtained at a cost below that of planting.[6] In most circumstances, adequate protection of advance reproduction is obtainable at only slight increase in logging costs. At Pole Creek (see also table 3), where only routine protection was given to the reproduction, the data in table 4 were obtained from a 1- by 1-chain grid of sample plots on a 10-acre area clear cut in 1955. Understory infestation here was fairly uniformly heavy, yet about half of the total (stocked and nonstocked) 1-milacre quadrats still bore uninfected trees after logging. On the basis of 4-milacre quadrats (a more realistic measure of stocking adequacy), 85 percent of the area was still stocked with uninfected trees after logging.

[6]Barrett, James W. Intensive control in logging ponderosa pine. Iowa State Jour. Sci. 34: 603-608. 1960.

Table 3. – Stocking and tree heights on

Locality, and infestation severity	Sample plots		Trees[1]	
	Number	Size	Total per acre	Infected
		Milacres	Number	Percent
Stand "C"				
Lightly infested	127	4	2,311	20
Heavily infested	185	4	1,274	67
Round Mountain				
Lightly infested	26	2 & 4	4,083	21
Heavily infested	47	2 & 4	2,918	57
Squaw Creek (part)				
Lightly infested	9	4	3,250	15
Heavily infested	36	4	2,201	53
Spruce Spring	103	1	4,922	59
Pole Creek, 1954 [3]	62	1	4,694	56
Pole Creek, 1958 [4]	57	1	4,649	59
Pole Creek, 1958 [4]	85	4	2,868	61

[1] More than 2 feet tall.

[2] Not more than 1 crop tree was tallied per plot in the "uninfected" column, and not more than 1 in the "acceptable" column. An "acceptable" tree was one with no visible stem infection and not more than 1 branch infection.

infested sample plots in reproduction

Average tree height		Plots with crop tree[2]		Average crop tree height	
Uninfected	Infected	Uninfected	Acceptable	Uninfected	Acceptable
Feet	Feet	Percent	Percent	Feet	Feet
7.0	9.3	94	97	11.5	12.2
5.0	7.9	57	64	6.7	7.4
4.9	7.6	96	96	7.6	8.2
3.4	6.8	70	79	5.2	6.1
3.0	5.6	100	100	4.2	4.2
2.8	5.6	83	89	4.0	4.7
3.1	5.6	73	83	4.0	4.4
3.6	5.4	76	92	4.4	4.9
3.9	6.4	68	77	4.8	5.2
4.0	6.6	87	89	5.5	6.0

[3] Before logging.

[4] 3 years after clear cutting.

Table 4.— Stocking on a heavily infested area before and after logging

Year of examination	Plot size	Plots			
		Total	Stocked	Infested	With uninfected tree
	Milacres	Number	Percent		
1954 (before logging)	1	98	84	63	68
1958 (after logging)	1	97	70	59	52
1958 (after logging)	4	97	96	88	85

STRUCTURE OF THE UNDERSTORY

Understory density has less effect than does tree size on suitability of an area for control – provided, of course, that sanitation will leave enough stocking to yield a return on the investment. Although the sanitation-thinning operation is more costly in dense than in sparse stands, most of the increase in cost is chargeable to the thinning.

Stands of saplings, especially of small ones, offer far better control opportunities than do pole stands. Less slash is created. Early thinning shortens the rotation. Examining the trees for infections is less expensive. Sacrifice of accumulated growth is held to a minimum. A higher level of stocking can be maintained, and greater freedom of choice in crop-tree selection permits better spacing of better trees.

Understories in heavily infested old stands have usually been long released by overstory mortality and consist predominantly of poles or of mixtures of poles and large saplings. Even under these conditions, sanitation-thinning of small infestations (less than an acre or

so in extent) may often be practical; however, control by present methods on large infestations in such stands is probably too costly.

In stands where overstory mortality has been relatively light, large infestations sometimes include extensive areas where understories consist principally of small- to medium-sized saplings. Such areas offer good chances for control. Less favorable chances, but still worth considering, exist where poles and large saplings are somewhat more common but where infection is light enough to permit sanitation without excessive sacrifice of stocking and accumulated growth.

Effects of understory structure on control possibilities may be illustrated by examples found in the course of a dwarfmistletoe damage survey near Squaw Creek, on the Deschutes National Forest. In these examples, it is assumed that stand structures for at least several chains to the sides of the survey lines are similar to those along the lines. This was true in most but not all instances at Squaw Creek.

In figure 4, line 1, conditions from about station 30 northward to station 98 appear favorable for control even though infestation is heavy enough to require sacrifice of much of the pole stocking. Percentage of area stocked with poles of all sizes averages less than 7, does not exceed 25 at any station, and exceeds 15 at only 5 of the 34 stations on this part of the line. Even where poles are most numerous, there need be little reduction in total stocking, since saplings are common under and immediately around the groups of poles.

Enlargement of the control unit southward 18 chains to the present boundary of the infestation might also be advantageous, although costs per acre would be somewhat higher. The southern edge of the control unit would then be protected from reinvasion, and spread of the infestation southward from station 12 would be prevented. North of station 98, however, the structure of the understory becomes more characteristic of infested old stands, and control appears impractical.

Along line 2, conditions appear favorable from stations 32 to 76. Pole stocking averages only 5 percent of

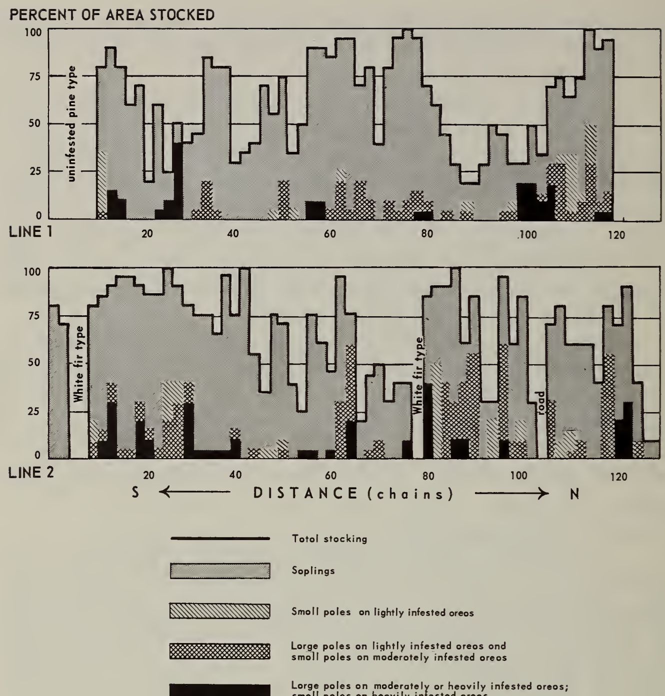

Figure 4.—Understory structure along two survey lines, 60 chains apart, in a large infestation. Stocking size class was determined by the dominant tree on each 2-milacre stocking unit. Data at each 2-chain station were estimated on a plot 1 chain in radius.

this area except at stations 62 and 64, and a strip of white fir type along a draw at station 78 will protect part of the edge of the control unit from reinvasion. Extension of the unit southward to the white fir type at station 8 would probably be too expensive because of the higher percentage of pole stocking and the generally moderate-to-severe infestation between stations 32 and 8.

These were two largest potential control units found on more than 17 miles of survey lines in this stand. In several other places, understories consisted mostly of saplings for 20-odd chains along the lines, but on units as small as these, unless they could be greatly extended at right angles to the survey lines, returns from control expenditures would be substantially reduced by reinvasion during the rotation. In such instances, control appears to be economically unsound except where reproduction consists almost exclusively of small saplings, where infestation is considerably lighter than the average in this stand, or where other especially favorable conditions permit control at an unusually low cost per acre.

DISCUSSION AND RECOMMENDATIONS

The principal objection to dwarfmistletoe control, aside from its cost, is that it requires clear cutting of infested areas and thereby delays harvesting of high-risk trees elsewhere. Although this objection has some validity, it is not necessarily true that partial cutting is always the best solution of the problem of high-risk trees. Accelerated deterioration of residual crowns immediately after logging, especially in seriously diseased stands, is so common that partial cutting often causes only a very temporary improvement in the average vigor of the mature stand and, within a few years, may actually increase the percentage of high-risk trees present.

At Squaw Creek, for example, dwarfmistletoe is by far the major cause of overstory decadence. Mortality has recently become so high that an immediate salvage cut is necessary; consequently, if any control is to be achieved here during the next century or so, the first steps must be taken now. If infested areas are only partially cut, additional heavy cuts every few years will be necessary because of rapid decline in vigor of infected residuals. After 20 years or so, most of the infected trees will have been salvaged, leaving infested areas in a practically clear-cut condition; but no progress will

have been made toward prevention of high-risk trees in the next rotation, and the young released trees will have become so much larger and more severely infected that sanitation is likely to be impractical. In such stands the indicated treatment is partial cutting where control is not needed or cannot be undertaken and clear cutting of infested areas wherever logging can be followed by control.

Recommended procedures for dwarfmistletoe control are:

1. Select the control units by a thorough ground reconnaissance shortly before logging (or, where conditions are known to be especially favorable for control, schedule logging for as early a date as possible).
   a. Give first priority to small patches and narrow salients of infestation, even though stand structures there may be somewhat less favorable than on larger units.
   b. Give second priority to larger infestations that can be entirely sanitized.
   c. Give third priority to those parts of extensive infestations where stand structure and infection conditions make control possible at low cost on circular or broadly oval units at least 20 acres in extent or on units whose boundaries can be located to take advantage of wide roads, nonstocked areas, and other barriers to reinvasion.
   d. Where conditions are otherwise similar, give approximately equal priority to light and heavy infestations unless infestation is severe enough to require excessive sacrifice of accumulated growth.
2. Where the control unit includes all of an infestation, clear cut to a distance of at least one-half chain outside the infestation. This lessens the chance that infected overstory trees will be left and gives additional release to the edge of the thinning. Where infestation continues beyond the boundary of the control unit, clear cut to a distance of at least 1 chain outside the unit to lessen reinvasion.

3. Sanitize the unit 4 or 5 years after clear cutting. Thinning can be done either at this time or when the unit is reworked. If the unit is sanitized immediately after clear cutting, two reworkings at intervals of 4 or 5 years may be necessary.
   a. Use experienced crews. Men new at the job miss many infections, but become much more efficient after a few days' practice.
   b. Numerous infections will be missed on dark days or when there is snow on the branches. If work must be done under these conditions, use a few man-hours on the first day of good visibility to eliminate missed infections.
   c. Cut all infected trees; except that markedly superior trees with not more than two infections, and trees whose removal would cause large gaps in the stand, may be left if pruned clean.
   d. If possible, leave about 30 percent more trees on light infestations and 60 percent more on heavy ones than are specified by spacing tables for the given site and size class.
4. Rework the unit 4 or 5 years later.
   a. Cut all infected trees, except that trees whose removal would cause large gaps in the stand may be left if they can be pruned clean.
   b. Cut enough of the uninfected trees to reduce stocking to spacing table specifications.
5. In all subsequent operations on the unit, discriminate against infected trees, and especially against those with brooms.

GPO 985-892